Knowledge Building and Knowledge Creation: Theory, Pedagogy, and Technology

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The terms "knowledge building" and "knowledge creation" entered the applied behavioral science literature at about the same time (Nonaka, 1991; Nonaka & Takeuchi, 1995; Scardamalia & Bereiter, 1991; Scardamalia, Bereiter, & Lamon, 1994), but in different domains: knowledge building in the learning sciences, knowledge creation in organizational science. Because they derive from different epistemologies, it was not immediately apparent that the two terms are essentially synonymous. "Knowledge building" derives from a Popperian epistemology that treats ideas as entities in their own right that can have properties, connections, and potentialities independent of the mental states of the individuals who hold the ideas (Bereiter, 2002; Popper, 1972; Scardamalia, Bereiter, & Lamon, 1994). Nonaka and his associates have treated knowledge creation as a socio-cognitive process in which the tacit knowledge of individuals figures centrally both as source and as outcome. The two are alike, however, in regarding new knowledge as being literally *created* rather than, as older epistemologies viewed it, *discovered.*

In both cases it was necessary to carve out a place for the creation of ideas in a conceptual space dominated by "learning"—as in "inquiry learning" and "learning organization." To demarcate this space in education we have distinguished between learning, conceived of as a change in mental state, and knowledge building, conceived of as the out-in-the-world production of designs, theories, problem solutions, hypotheses, proofs, and the like. The two may go on in parallel, and are expected to do so in education, but from a design standpoint they represent different problem spaces. "Group cognition" (Stahl, 2006), a new kid on the epistemological block, does not obviate the distinction. Groups can learn—that is, acquire skills and understandings best described at the group level. At the same time, but from an importantly different viewpoint, knowledge creation frequently has its origin in group processes. To emphasize the distinction, we have adopted the convention of capitalizing Knowledge Building to refer to the approach elaborated in this chapter, which aims to bring into education both the goals and the processes of knowledge-creating organizations—as represented, for instance, in scientific research groups and industrial design teams.

In successful knowledge-creating organizations, invention and design are "part-and-parcel of the ordinary, if not routine" (Drucker, 1985) and people are recognized for contributions they make to the organization's or community's knowledge, not for what is in their minds. In education, the opposite is normally the case. Although students may be rewarded for doing good work, the "good work" (written assignments, and so forth) is usually valued as evidence of what is in the student's mind—hence as evidence of learning. However, in Knowledge Building theory, pedagogy, and technology, students' work is primarily valued for what it contributes to the community and secondarily for what it reveals about individual students' knowledge.

In judging whether students are actually capable of authentic knowledge creation. we have argued that students should not be held to a higher standard than university researchers who publish and earn tenure on the basis of original contributions to knowledge, but who are not the Einsteins or Piagets of their fields (Bereiter & Scardamalia, 2010). Insightful interpretations or explanations of the work of others qualify as knowledge creation, as do identification and clarification of problems, providing supportive or disconfirming findings, offering a different perspective on an issue, and even popularizing knowledge advances—putting them within reach of the less sophisticated. All of these are within the capacity of school students working collaboratively (van Aalst, 2009; van Aalst & Truong, 2011). The community to which knowledge contributions are made is normally the community of their peers, but this does not exclude occasionally making contributions to world knowledge writ large. The same is true, of course, in the corporate and research worlds.

Despite the recognizable value of group knowledge-creating activity, the fact remains that schools are held responsible for individual students' learning. Educational activities, which may range from taking notes in a lecture to creating a theory or a computer simulation, are ultimately judged according to what individual students learn from them. Such judgments fuel long-running debates about educational policy and no educational approach can stand aloof from them. As far as conventional measures of learning are concerned, evidence indicates that Knowledge Building enhances learning in relevant areas and does not diminish learning in others (Scardamalia, et al., 1992; Chuy, et al, 2010), and that as promotion of collaborative knowledge building advances, individual learning of subject matter advances with it (Zhang, Scardamalia, Reeve, & Messina, 2009). Advances in literacy have been documented in the absence of reading instruction, apparently due to students' sustained engagement in knowledge-building activities that provide authentic motivation for reading and writing (Sun, Zhang, & Scardamalia, 2010).

Over and above traditional learning objectives, however, is the objective of equipping students for the emerging conditions of life and work in an innovation-driven knowledge society. Many contemporary approaches pursue this objective—some through testing and promoting what are popularly called "21st century skills," others through engaging students in activities that have some of the characteristics of work in knowledge-creating organizations. Knowledge Building, however, takes a more direct approach, making knowledge creation itself the constitutive basis of subject matter education—in brief, acquiring competence in knowledge creation by actually doing it. In broad terms, this means enabling all students to find respected and positive roles as collaborators in knowledge creation.

Although Knowledge Building and knowledge creation refer to the same process, in practice Knowledge Building encompasses a much greater range of concerns, due in large part to its involvement in issues of learning and human development. These issues are not entirely absent from organizational knowledge management, but they do not have nearly the prominence there that they have in educational Knowledge Building. Thus the term "Knowledge Building" identifies a distinctive design space, even though conceptually it is synonymous with knowledge creation. In the following sections we elaborate five themes that represent special challenges that must be faced when knowledge creation is brought into education.

1. Community Knowledge Advancement

Creative knowledge work may be defined as work that advances the state of community knowledge, however broadly or narrowly the community may be defined (Scardamalia & Bereiter, 2006). In every scholarly discipline one finds periodic reviews of the state of knowledge (or the "state of the art") in the field. Different scholars might offer different descriptions of the discipline's state of knowledge; however, these disagreements may themselves contribute to advancing the state of knowledge. The state of knowledge is not what everyone in the field or the average person in the field knows, but neither is it what the most knowledgeable people in the field know. Rather, it is an emergent collective phenomenon, a distributed characteristic of the entire discipline. And in this sense, the state of knowledge cannot be found in any one person's mind. If we look back at prehistoric times, using archaeological evidence, we can make statements about the state of knowledge in a certain civilization at a certain time, without knowing anything about any individuals and what they thought or knew.

Knowledge Building pedagogy is based on the premise that authentic creative knowledge work can take place in school classrooms—knowledge work that does not merely emulate the work of mature scholars or designers but that substantively advances the state of knowledge in the classroom community and situates it within the larger societal knowledge building effort. As in the scholarly disciplines, the state of knowledge in the classroom is an emergent distributed phenomenon that cannot be found in any one student's mind. Correspondingly, the state of community knowledge only indirectly reflects the knowledge of individual members of the community. Some individuals may lag behind, some may be in advance, and some off in another direction from the progress of community knowledge. It is, however, reasonable to expect (as evidence from a variety of sources indicates) that advances in community knowledge will be accompanied by gains in individual achievement. In the previously cited study by Zhang, et al (2009), year-by-year changes in a teacher's practice aimed at getting fuller participation in collaborative Knowledge Building resulted in both sociometric changes in the desired direction and also progressive improvements in learning results over successive years.

2. Idea Improvement

Engineers and designers do not think in terms of a final state of perfection (Petroski, 1998). Advances in a technology open up new problems to be solved and new possibilities for further advancement; there is no end in sight. But many people still think of scholarly knowledge as advancing toward (though perhaps never reaching) final truths: how the universe actually began, the true history of the invasion of Iraq, and so on. But advances in theoretical and historical knowledge raise new problems and open new possibilities, just as do advances in technology. In Knowledge Building, idea improvement is an explicit principle, even at elementary school levels (Scardamalia, 2002). More than a pedagogical principle, idea improvement is promoted as a socio-cognitive norm intended to inform the whole way of life in a knowledge-building community. Every idea is to be treated as potentially improvable. In such a socio-cultural environment, "critical thinking" is manifested not so much by skepticism or argumentativeness as by the pervasive application of "design thinking" (Martin, 2009)—continual application of a "make it better" heuristic rather than an "arguments for/arguments against" heuristic (Bereiter & Scardamalia, 2003).

In any educational program, students are expected to leave with better ideas than they held initially. Educational programs vary not only in their methods of promoting idea improvement but in the allocation of responsibility for bringing such improvement about. In conceptual change teaching, for instance (see diSessa, this volume), it is generally accepted that idea improvement must come from the students' own reconciliation of conflicting conceptions, but the teacher is responsible for recognizing conceptual inadequacies, arranging activities that will induce cognitive conflict, and assessing results. In Knowledge Building, however, students are expected to take on these responsibilities themselves, with help from teacher, technology, and peers. Whereas idea generation comes naturally to young people, working to improve one's ideas does not. Considerable support is usually required to maintain student engagement in idea improvement, and even more to establish idea improvement as a classroom norm. But once it is established the students themselves become a sustaining force. As later sections of this chapter will show, supporting sustained creative efforts at idea improvement is the principal challenge in designing more powerful knowledge-building technology.

3. Knowledge-Building Discourse

In a view of science that was common among philosophers of science 50 years ago, the essential value of discourse among scientists comes from sharing knowledge and subjecting ideas to criticism, as in formal publications and oral presentations, question-and-answer sessions after these presentations, and occasionally debates. Essentially, discourse was viewed as a filter, determining what was accepted into the canon of justified beliefs (Latour & Woolgar, 1979). Lakatos (1976) was perhaps the first to argue that real science does not work this way; instead, discourse often plays a creative role—actively improving on ideas, rather than only acting as a critical filter. Empirical studies of scientific discourse have supported this view. For example, Dunbar (1997) showed that the discourse that goes on inside research laboratories is fundamentally different from the discourse that goes on in presentations and papers; it is more cooperative, more concerned with shared goals of advancing understanding beyond what is currently understood. The creative role of discourse is also widely recognized in the organizational knowledge creation literature; for example, it is the centerpiece of Tsoukas' (2009) theory of knowledge creation. Public discourse and collaborative discourse serve complementary functions, and practitioners of a discipline need to be proficient in both (Woodruff & Meyer, 1997). In Knowledge Building, adversarial argumentation has a role but collaborative discourse is the driver of creative knowledge work.

4. Constructive Use of Authoritative Information

The use of authoritative information has presented problems for educators ever since the advent of student-centered and constructivist education. On the one hand, we do not want students to meekly accept authoritative pronouncements. On the other hand, it is impossible to function in society without taking large amounts of information on authority. Even when it comes to challenging authoritative pronouncements, doing so effectively depends on bringing in other authoritative information as evidence. A focus on knowledge building helps to resolve these problems. Information of all kinds, whether derived from first-hand experience or from secondary sources, has value insofar as it contributes to knowledge building discourse.

The explosive growth of web-based information has raised the bar on what constitutes adequate literacy. According to Alan Liu (2012), "long forms of shared attention" (of which the scholarly textbook is a salient example) are giving way to short forms (of which the “Tweet” is an extreme example). As a consequence, the job of producing coherence, a responsibility traditionally borne by the author or lecturer, has now devolved upon the reader or viewer. Beyond the ability to use a variety of informational and expressive media (multiliteracy), the new “open world” of information requires the ability to construct coherent knowledge out of fragmentary information, which Liu has termed “transliteracy.” Use of multiple documents in learning has become an active research area in the learning sciences (Britt & Rouet, 2012; Goldman & Scardamalia, 2013). Coherence-building is a legitimate type of knowledge creation, an essential part of making constructive use of available information rather than a preliminary or adjunct to it. Students doing Knowledge Building are thus of necessity practicing transliteracy and can profit from technology and pedagogy that supports it.

Understanding through Collaborative Explanation Building

In the kinds of knowledge-creating organizations studied by organization scientists, knowledge creation is usually directed toward practical goals such as product innovation and solution of operational problems. In the pure sciences and scholarly disciplines, however, the top-level goals of knowledge creation are typically understanding and explanation. These are also top-level goals of school subjects, increasingly so as standards and achievement tests shift away from emphasis on recall to emphasis on evidence of understanding. In education for a knowledge society, it is important that students have experience in building knowledge serving practical purposes—such as product design and solution of socially significant problems. Although active in promoting innovativeness along practical lines, the Organization for Economic Co-operation and Development (OECD) has emphasized the importance of conceptual understanding as a basis for creative knowledge work of all kinds: "Educated workers need a conceptual understanding of complex concepts, and the ability to work with them creatively to generate new ideas, new theories, new products, and new knowledge" (OECD, 2008, p. 1).

Besides basic theoretical concepts, innovation also depends on a supply of "principled practical knowledge," defined informally as "know-how combined with know-why" and more formally as "explanatorily coherent practical knowledge" (Bereiter, in press). This is knowledge created in the process of solving problems but requiring additional investment of effort in producing knowledge useful beyond the immediate problem—knowledge sufficient to enable a field of practice to advance. In schools that make use of work-study arrangements, field trips, service learning, and the like, it is common practice to accompany these with discussions aimed at connecting the students' concrete experiences to more generalizable knowledge. In this context, Knowledge

Building represents what may be called a principled way of producing principled practical knowledge.

Knowledge Building Pedagogy

Knowledge Building pedagogy puts the emphasis on guiding principles rather than prescribed procedures (Scardamalia, 2002; Zhang, Hong, Scardamalia, Teo, & Morley, 2011). While many innovative educational approaches enunciate guiding principles, most accompany these with explicit procedures to help teachers translate the principles into practice—for instance, the "activity structures" of Brown and Campione's (1996) "communities of learners." "Orchestration scripts" (Dillenbourg & Jermann, 2006) have made headway in instructional science by offering explicit proceduralization (sometimes to foster knowledge creation: Weinberger, et al, 2005; Sandoval & Reiser, 2004).

Teaching, of course, is carried out through procedures of some kind. A significant drawback of prescribed procedures, however, is that they can easily degenerate into what Brown and Campione (1996) called "lethal mutations"—procedures that take on a life of their own and evolve in ways that undermine the purposes for which they were originally designed. Procedures should evolve. The problem is getting them to evolve in favorable ways, given that the evolution of practices, like biological evolution, is essentially uncontrollable and unpredictable as to specifics. Principles such as "authentic problems, real ideas," "epistemic agency," and "improvable ideas" (Scardamalia, 2002) can serve an important regulative function for both teachers and students, helping to keep higher-level goals in mind and to prevent "lethal mutations" or reversion to older practices. Students themselves can come to use knowledge building principles in conceptualizing their own work. Caswell and Bielaczyk (2001) reported students' productive use of the principle of "improvable ideas." In another class, elementary school students in an inner city school—identified as one of the neediest in Toronto—studied and began to apply such principles as epistemic agency, pervasive knowledge building, and community knowledge, and to describe their work at an international conference. We would not categorically reject procedural prescription; local conditions may sometimes necessitate it. But, as we have emphasized, education for knowledge creation and innovation poses many unsolved problems. Effective solutions require not only design research from the learning science community but also invention by teachers, administrators, engineers, and students themselves. Later in this chapter we will indicate technology designs and institutional arrangements for "hubs of knowledge building innovation" intended to support such invention. The point we want to emphasize here, however, is the importance of having regulative principles and generative procedures that stimulate and guide rather than impede pedagogical invention.

Knowledge Building Technology

CSILE (Computer Supported Intentional Learning Environment), implemented in 1983, represented our first effort to develop networked computer applications to provide these kinds of support for knowledge building. Knowledge Forum®, launched in 1995, provided stronger support for community knowledge (Scardamalia, 2004) at all educational levels and in non-educational settings. And now an international open source community is designing extensions to better support the goals identified above and to ensure interoperability with other platforms, social media and mobile technologies.

Knowledge Forum is a multimedia knowledge building environment, with its content and organization created by users. The community knowledge spaces (views) that users create and the ideas they contribute (notes) are themselves collectively emergent phenomena, representing the advancing knowledge of the community. The *view* provides the organizing contexts--possibly a diagram, a scene, a model, a concept map, etc.--to give structure and meaning to the *notes* whose titles appear in it. The view background can be created before, during, or after work on the view begins, and can be edited at any time. Notes are contributed to the view, with titles on the view providing an overview of issues being addressed. Notes are similarly editable and movable; the same note may appear in multiple views.

Figure 1 illustrates a student-generated graphical background, with notes contributed by students as work proceeds. Each learner contributes notes that can then be read by any other student, with notes built on or responded to by others. Lines between notes show note linkages resulting from students building on and referencing each other. In this way, the community builds knowledge, with their collective contribution displayed on the view, and each view represents the emergent collective knowledge.

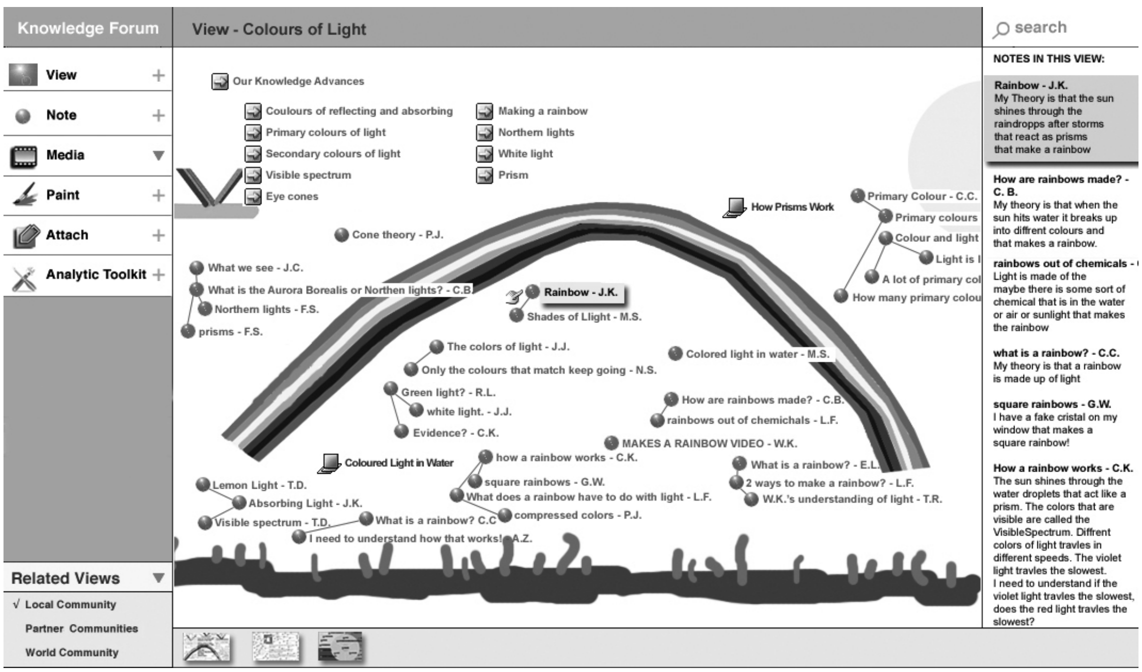

Figure 1: A Knowledge Forum view supporting user-generated graphical representations of notes and note linkages.

Figure 2 shows one note by one student contributor to the community space. Directly to the left of the note are easy-to-use theory-building scaffolds (My Theory, I Need to Understand, New Information, etc.). As the note text indicates, the student has elected the My Theory scaffold. At the bottom of the note are options for actions on notes including “build on,” “annotate,” and “reference.” To the right is a list of notes corresponding to a search (e.g., notes in the view sharing the same scaffold type as the open note, notes sharing keywords, near semantic neighbors).

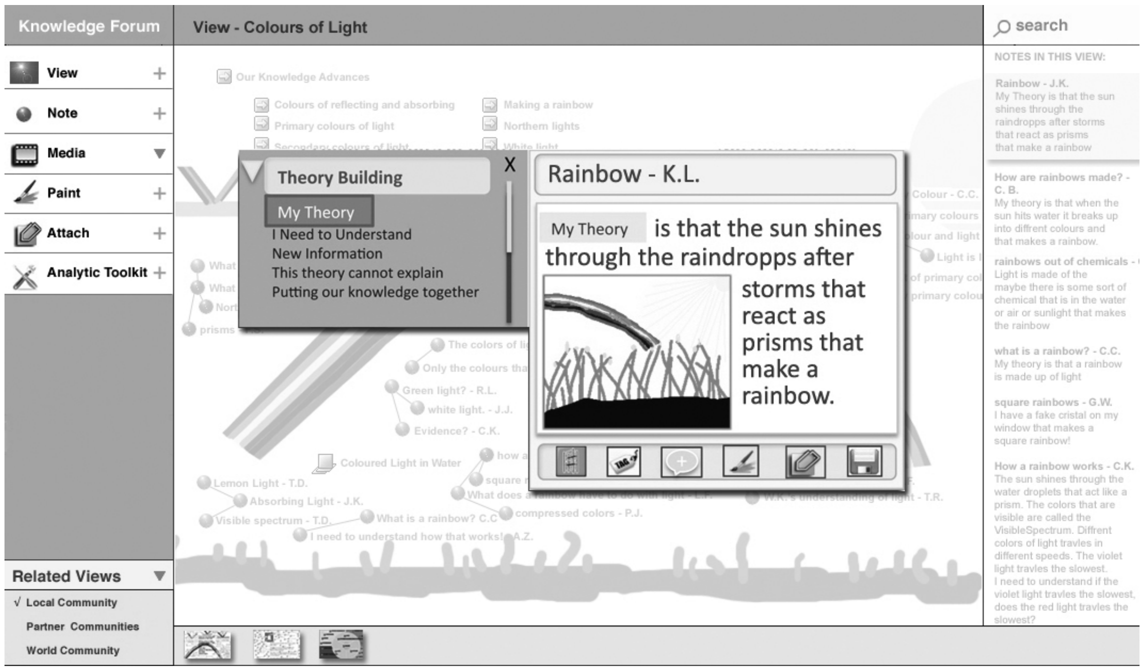

Figure 2: A Knowledge Forum note supporting user-generated graphical representations and text, with a theory-building scaffold.

Wherever one is in a Knowledge Forum database, it is always possible to move downward, producing a lower-level note, comment, or subview; upward, producing a more inclusive note or a view of views; and sideways, linking views to views or linking notes in different views. Notes themselves may contain graphics, animations, movies, audio, links to other applications and applets, and so on. Knowledge Forum lends itself to a high level of what we call “epistemic agency” (Scardamalia, 2002). Although the term has different meanings in different contexts, in Knowledge Building epistemic agency refers to the control participants have over the whole range of components of knowledge building—goals, strategies, resources, evaluation of results. Toward this end, views--as well as their contents--are designed by users, or by authorized visitors, partner classes, or invited others from outside the class. Similarly, scaffolds are customizable.

We have seen students actively engaged in designing scaffolds to support more productive thinking. For example, one fourth-grade class decided that they were doing too much "knowledge telling" and so they introduced new scaffolds to focus attention on advancing their ideas. And Knowledge Forum scaffolds are designed to be used opportunistically, without a set order. Of course, nothing prevents scripting activity so that every student is engaged in a common, phased process (some learning software is designed with such structuring of activity built in). But in keeping with the Knowledge Building goal of learning innovation by engaging directly in the process, we recommend that scaffolds and other Knowledge Forum functions be used opportunistically, as users see fit, and in no fixed order. The results have been impressive and have suggested that students can take on even more demanding roles, as we elaborate below in the section titled "Supporting Sustained Creative Work with Ideas."

We designed Knowledge Forum not simply as a tool, but as a knowledge building *environment*—that is, as a virtual space within which the main work of the group takes place (Scardamalia, 2003). Giving pragmatic support to the idea that the same process underlies both school learning and high-level knowledge creation, Knowledge Forum has been used without modification at levels ranging from kindergarten to graduate school and professional work.

Students using Knowledge Forum do not spend all their knowledge-building time at the computer. They read books and magazines, have small-group and whole-class discussions, design and carry out experiments, build things, go on field trips, and do all the other things that make up a rich educational experience. But instead of the online discourse being an adjunct, as it typically is in instructional management systems, Knowledge Forum is where the main work takes place. It is where the "state of knowledge" materializes, takes shape, and advances. It is where the results of the various off-line activities contribute to the overall effort. If students run into a problem, they often recommend starting a space in Knowledge Forum to preserve and work out the ideas. Students come to see it as a valuable place for idea improvement. At the end of Grade 1, a child moving to a class without Knowledge Forum asked, "Where will my ideas go? Who will help me improve them?" The grade 2 teacher decided to use Knowledge Forum; the child's grade 1 ideas lived on, to be improved along with new ideas generated in grade 2.

Supporting Sustained Creative Work with Ideas

Supporting the engagement of all students in sustained creative work with ideas (emphasis on *sustained*) has proved to be the most challenging problem in designing knowledge-building/knowledge-creating technology. It is a design challenge that carries with it the other challenges discussed earlier in the five themes. In this section we discuss design solutions that are currently at an experimental stage prior to being incorporated into the new open source version of Knowledge Forum.

Two planned enhancements to the existing knowledge-building environment are intended to support idea work and move it to higher levels. One is supports for "metadiscourse"—student discourse about an ongoing knowledge-building discourse, concerned with evaluating progress, recognizing and dealing with obstacles, and so on. The other is stronger visual support for the idea of "rising above"—forming higher-level syntheses of ideas. Figure 3 shows one simple tool to aid metadiscourse: a graph of frequency of use of various scaffolds.

Figure 3. Metadiscourse “Scaffold Meter” showing frequency of use of Knowledge Forum scaffolds by grade 2 students at a midpoint in their work on explaining how birds fly.

In a trial of the "Scaffold Meter" illustrated in Figure 3, grade 2 students were working in a view titled “How do birds fly?” On viewing the graph, which was superimposed on their view of the same name, the students quickly focused on the fact that they had generated many theories about how birds fly but not much in the way of authoritative source information (e.g. the “important information + source” scaffold shows low levels of use). They also noted that there was very little effort to explain why source information is important (the scaffold “this information helps explain” was almost never used). The discussion stimulated by these results conveyed an awareness of issues not evident to teacher or students previously. And students immediately took responsibility for remedying problems. For example, they decided to read books to find information relevant to their theories. As a result, a discourse that had seemingly come to an end prior to this intervention took a new and productive direction (Resendes, Chen, Chuy. & Scardamalia, 2012; Resendes, Chen, Acosta, & Scardamalia, 2013).

Knowledge Forum has since 1995 supported movement toward higher-level synthesis of ideas through rise-above notes and views. The view shown in Figure 1 contains rise-above notes, marked by lines under the note icon (notes titled "Coloured Light in Water" and "How Prisms Work"). Hierarchies of views are represented by the arrangement of view links at the top of the view in Figure 1. Greater visual impact is needed to convey a sense of ideas existing at different levels of inclusiveness and explanatory power.

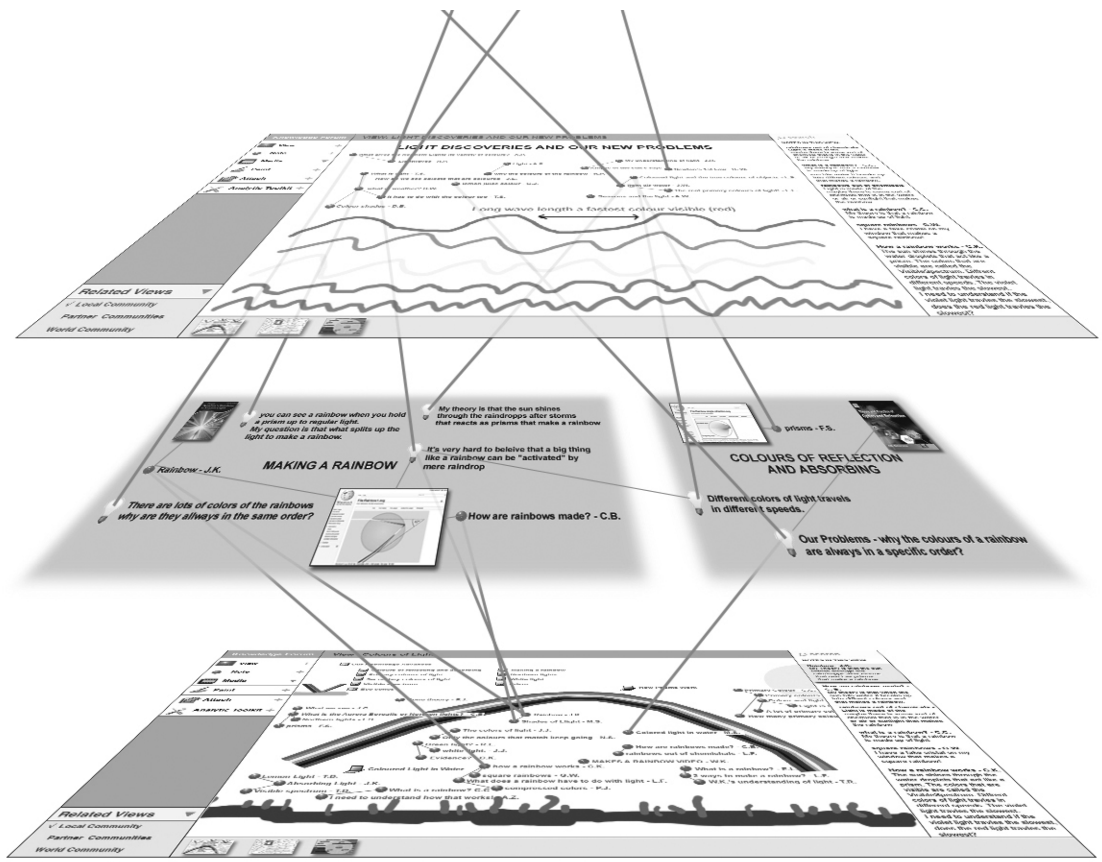

Figure 4: Rise-above graphical user interface for next-generation knowledge building technology. Students' ideas that provide greater explanatory coherence are shown as rising to a higher plane.

Figure 4 suggests a possible multi-level design. At the bottom level, students' notes appear as they do now. In relation to a general problem defining the view, individual notes may contain questions, problems of understanding ("I need to understand"), relevant information drawn from various sources, explanatory ideas, and so on. Ideas selected as promising and warranting further work are represented at the next higher level, with links back to their parent notes. Work on developing and improving these ideas takes place at this higher level. Based on this work, complex idea structures (e.g., theories or theory-like constructions, models, identification of new problems and action plans) are represented at the next higher level, and so on. Thus progress in knowledge creation is registered not so much by successive approximation to authoritative information (which in essence is what knowledge tests, including essay examinations, generally measure) but by vertical progress toward greater explanatory coherence. Research to date shows that a good predictor of work on exams is level of collaborative engagement and depth of understanding evidenced in work in Knowledge Forum (Chan, Lam, & Leung, 2012).

In addition to a visual metaphor, supports are needed to aid students in reconstructing ideas at progressively higher levels. The most elementary requirement is a way of marking promising ideas at one level and assembling them at the next higher level for further work. The "promisingness" tool (Chen, et al, 2012) allows users to clip promising ideas from their own or from peer notes. Selected ideas can then be ordered from most to least promising, based on number of selections of the same idea. The selected ideas can then be made the basis for group discussion of next steps. Or, selected ideas can be exported to new views. A link is preserved to the full note from which an idea was clipped. In keeping with the concept of Knowledge Building discourse discussed earlier, use of the promisingness tool requires that ideas found elsewhere be brought into the collective discourse. Thus, for example, we see, in the middle section of Figure 4, promising ideas—marked by lightbulb icon--linked to resource material and new student notes. Efforts to synthesize information in an intermediary workspace help students advance their thinking to the next highest level.

In pilot research in a grade 3 class (Chen, Scardamalia, Resendes, Chuy, & Bereiter,, 2012) a simple procedure was used: students clipped promising ideas and in a whole-class discussion reviewed ideas selected, ordered from most to least hits, and selected 3 ideas to be moved to a new view, knowing--as they made selections--that the new view would be their new community workspace. This led to an important discussion regarding ideas worth working on further. The process was repeated. These two iterations of selecting promising ideas and refocusing work on them led to significant knowledge gains, as compared to the rated quality of note contents from the previous year's class of students at the same grade level, working on the same unit, with a more experienced teacher but without access to the tool. The teacher felt the result was clearly attributable to use of the tool.

A hypothesis being pursued through ongoing research is that students can consistently select the most promising ideas from those they have generated, resulting in year-by-year advances in what they can accomplish. Overall, pilot research to date indicates that selecting promising ideas and refocusing discourse on a smaller set of ideas--judged by the students to be promising--helps rekindle interest, reduce information overload, direct knowledge-building effort along more productive routes, and achieve higher levels of individual learning (Chen, Scardamalia, Acosta, Resendes, & Kici, 2013).

To support the actual production of higher-level ideas, more powerful tools are needed. We envision a palette of such tools constituting an integral part of Knowledge Forum, available for use by teachers and students at any point in the knowledge-creating process. Social network analysis has already proved valuable in research on knowledge-building processes (Philip, 2010; Zhang, et al, 2009). The Idea Thread Mapper (Zhang, Chen, Chen, and Mico, 2013) re-represents Knowledge Forum notes in time-ordered progressions, based on notes referring to preceding notes. Semantic analysis of note content holds the promise of aiding knowledge building efforts, provided it goes beyond identifying note topics and makes connections based on what is being said about the topics. KB-Dex is a highly versatile knowledge building discourse tool that combines social and semantic analysis for rendering social-semantic relations visible and has already been used effectively with students working in Knowledge Forum (Oshima, Oshima, & Matsuzawa, 2012).

The intent in next-generation technology is to support customization, including the analytic tool palette, and to design the tools so that they empower both students and teachers. Making tools accessible for student use poses both usability problems and ethical issues to be addressed by designs that ensure anonymity, as appropriate, and that provide useful information while avoiding invidious comparisons of students and efforts by them to "game the system." Past experience has suggested that students can work with ideas at surprisingly high levels of sophistication, and that they are impressive design partners, able to help advance designs for knowledge practices and technologies for sustained work with ideas.

Current Directions

Designing education to meet the emerging needs of a knowledge society is a priority of education systems worldwide. At this writing, it appears that these efforts are dominated by test-driven “21st century skills” approaches, often sponsored by major corporations. In recent months, however, we have found education officials in widely separated jurisdictions resonating to the idea of “*beyond* 21st century skills.” Although no one is likely to question the value of creativity, problem solving, collaborativeness and other items that are central 21st century skills, there are serious questions of teachability, transfer of learning, and test validity that tend to be glossed over by “21st century skills” enthusiasts. Experienced educators recognize that tacking the word “skill” onto a desirable human trait does not make it teachable, and so they are likely to find expressions like “empathy skills” ludicrous. Furthermore, to educators who have been in the business for enough years, the skills movement evokes a “been there, done that” reaction. It is not much different from “higher order thinking skills” and related movements that have come and gone over the past 6 decades. With the Knowledge Building approach we aim to provide a relatively clear-cut way of going beyond programs focused on assessing and teaching 21st century skills. By engaging students and teachers as active participants, along with researchers, engineers, and policy makers, we aim to establish pedagogical models and technologies that provide an alternative with potential to exceed existing curriculum standards and expectations.

Researchers and innovators involved in Knowledge Building have launched two initiatives to advance it as an approach to education for a knowledge society. One is a membership association, Knowledge Building International-- http://ikit.org/kbi/. The other is an international project called “Building Cultural Capacity for Innovation” (BCCI). It has wide-ranging objectives, including: research to solve problems such as those discussed in this chapter, creation of “hubs of innovation” to support pedagogical invention and its dissemination, and open source development of Knowledge Building environments, assessment tools, and resources for “learning to create knowledge by doing it.” BCCI has both a knowledge advancement side and a promotional side. As this chapter has suggested, there are major design challenges yet to be satisfactorily met; finding ways to achieve full engagement of all students in sustained efforts at idea improvement is a salient example, but there are others. At the same time, securing a place for Knowledge Building in school programs that are already fully committed to worthwhile educational activities requires more than evidence of good results. It requires putting across a new vision of what is possible. For that reason, one of the important functions of BCCI will be collecting and publicizing examples of school children producing and elaborating ideas that parents and journalists will recognize as authentic knowledge creation.

In keeping with the principle of "improvable ideas" discussed earlier, it must be recognized that Knowledge Building itself is grounded in improvable ideas. Some of these are being improved through other research programs. For instance, "explanatory coherence," which has long been a key idea in Knowledge Building, has undergone extraordinary development by Thagard and his collaborators. What was once a schema mainly relevant to scientific explanation has since been elaborated so that it incorporates not only logical but also social, emotional, and neurologically constrained determinants of explanatory coherence (Thagard, 2000, 2006). This makes it directly applicable to case-based theories in history, social studies, and humanities, where motives are an essential element; and this, in turn, brings theorizing in these areas into the mainstream of educational Knowledge Building (Bereiter & Scardamalia, 2012). Other idea improvements may come about by efforts to synthesize Knowledge Building with other approaches or other cultural forms Chan (2011). A number of investigators have explored linking Knowledge Building with "near neighbors": e.g., problem-based learning (Hmelo-Silver & Barrows, 2008; Lu, Bridges, and Hmelo-Silver, this volume), "epistemic games" (Bielaczyc & Kapur, 2010), "group cognition" (Stahl, 2006), and open source communities (Hemetsberger & Reinhardt, 2006). However, the most direct forms of improvement in Knowledge Building are likely to come about through building principled practical knowledge (Bereiter, in press) in the course of producing pedagogical and technological inventions to solve actual problems of implementing Knowledge Building in diverse settings. That is what "knowledge building hubs of innovation" are expected to produce in the BCCI project.

Conclusion

A case study by Zhang, et al (2011) concluded that principle-based knowledge building, if it is to prevail, requires a continuing process of knowledge building by teachers themselves, resulting in educational designs that achieve continually closer approximations to ideal principles. Perhaps more than anything else, however, a principled knowledge building approach must contend with a contrary set of widely-held beliefs: namely, (a) basics must be mastered before students can undertake higher-order work with ideas, and (b) instructional planning must start with a clear specification of the skills and concepts to be learned. These are notions that survive from an era before the emergent, self-organizing character of learning and cognition was well recognized. They are not based so much on evidence as on what was perceived as common sense in those simpler times.

Although these "instructionist" approaches (Sawyer introduction, this volume) may have value for the routine conduct of instruction, they are barriers to the more open-ended approach that education for a knowledge society requires. Even such a basic goal as literacy is changing, and will probably continue to change, as a result of new technologies that affect the forms and flow of information. An instructionist approach might be capable of incorporating new informational media as they arrive, and might develop new objectives having to do with skills in the use of the new media.

But deeper things are happening, as noted in our brief discussion of transliteracy. The emerging literacy challenge is to build coherent knowledge out of fragmentary information coming from multiple sources. Although this challenge is beginning to be researched, the requisite skills and strategies are not yet well understood, much less how to foster them. Trying to nail down specific objectives and to order them into a developmental sequence is obviously premature, and yet schools should be trying to do something to help today's students contend with transliteracy challenges (of which they may be quite unaware). More generally, there is a need to go beyond simplistic objectives to deeper and more consequential ones. Getting stakeholders together to formulate objectives (as in the drafting of 21st century skill goals) is not going to suffice. We need to learn from our students what the next iteration of goals needs to be, and that means putting students into an educational environment where new competencies and new problems have a chance to emerge (Scardamalia, Bransford, Kozma, & Quellmalz, 2012).

Knowledge Building aims to provide such an environment. While it may seem to be a radically optimistic approach, it is actually quite cautious in making assumptions about what is teachable and what the goals of 21st century education should be. As for the question of what students are actually capable of, the Knowledge Building answer is, "Let's find out."

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